ANALOG DEVICES

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APPLICATION NOTE

ONE TECHNOLOGY WAY • P.O. BOX 9106 • NORWOOD, MASSACHUSETTS 02062-9106 • 617/329-4700

Overvoltage Protection for the ADG5XXA Multiplexer Series

by Dan Sheehan

The ADG5XXA* multiplexer series is a family of single 8/16 channel and dual 4/8 channel parts. They are available in both latched (ADG52XA) and unlatched (ADG50XA) versions. These are high performance multiplexers that offer the following notable features: specifications for both single and dual supply operation, 1nA max leakage current, 200ns max turn-on and turn-off times and TTL compatibility with reduced single or dual supplies down to 5V.

The multiplexers are specified to operate with an analog input signal range within the supply rails, i.e., $V_{SS} \leq V_S (V_D) \leq V_{DD}$. The parts are not internally overvoltage protected (i.e.,with resistors) to allow V_S (V_D) to exceed the power supply rails. Thus, the ADG5XXA series, without external overvoltage protection, is best suited for use in systems where the analog input signals come from sources within the system, such as from op amps powered from the same supplies as the multiplexers.

However, in many applications such as process control systems, the analog input signals can originate from sources external to the system which contains the multiplexer.This can be potentially destructive to the multiplexer for two principal reasons:

1. The multiplexer power supplies may be turned off while the analog signals are still present.
2. The signal lines may receive induced voltage spikes which exceed the supplies to the multiplexer.

This application note addresses the above problems and outlines the protection circuitry required to allow the analog input signals to exceed the supply rails over the −40°C to +85°C temperature range.

OVERVOLTAGE PROTECTION: WHY?

The following is a brief and simplified analysis of what happens when a signal applied to the S(D) input of the multiplexer exceeds the power supply rails. The results outlined apply equally with the power supply rails at ±15V or GND.

*ADG506A/ADG507A, ADG508A/ADG509A, ADG526A/ADG527A, ADG528A/ADG529A.

The basic CMOS switch consists of an n-channel MOSFET in parallel with a p-channel MOSFET. This structure which yields an excellent analog switch contains p-n junctions between the signal path and power supplies. These p-n junctions or diodes are reverse biased under normal operating conditions, i.e., $V_{SS} \leq V_S (V_D) \leq V_{DD}$. However, if V_S (V_D) exceeds either power supply rail by approximately 0.7V, the normally reverse biased junctions will become forward biased. This means that with an analog input overvoltage, the S(D) input of the multiplexer will appear as a diode connected to the relevant power supply voltage. Therefore, $V_S(V_D)$ is clamped to a maximum of 0.7V greater than either supply rail and large currents can flow that will destroy the parts unless restricted. The simplest form of protection uses resistors in series with the S (D) inputs to limit the input current to safe levels.

PROTECTING TYPICAL MULTIPLEXER APPLICATION CIRCUITS

This section shows two typical multiplexer application circuits and outlines the operating conditions and protection circuitry required for the safe operation of the parts with an overvoltage on the analog inputs. The ADG506A is shown in both circuits but the same conditions and results apply to any part in ADG5XXA series.

Generic Multiplexer Circuit

Figure 1 shows the general use of a multiplexer. R1–R16 (2.7kΩ) provide overvoltage protection.

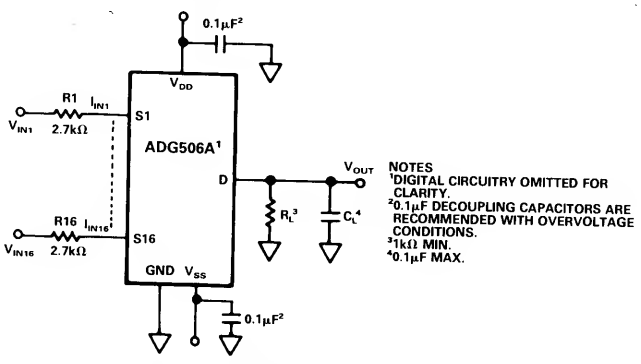

Figure 1. ADG506A Multiplexer Circuit

The series resistors are sufficient to protect the multiplexer over the −40°C to +85°C temperature range under the following conditions:

- V_{DD}/V_{SS} = GND with ±15V max applied continuously to all the analog inputs ($V_{IN1} - V_{IN16}$).

  With the supplies at GND, V_S and V_D are clamped to ±0.7V max. The total analog input current ($I_{IN1} - I_{IN16}$) is limited to 85mA max ([14.3V/2.7kΩ]×16).

  Power on/off is also allowed with $V_{IN1} - V_{IN16}$ = ±15V, but V_{DD} and V_{SS} must power on/off within 0.5 seconds max of each other. The protection outlined is adequate with power supplies that remain low impedance in the off state. However, if the supplies go high impedance or open circuit in the off state, additional protection such as 15V TransZorbs* connected from both V_{DD} and V_{SS} to GND is recommended. The TransZorbs are recommended to suppress any transient voltages exceeding the Absolute Maximum Ratings of the multiplexer. Excessive transients commonly occur when powering-on supplies that are high impedance or open circuit in the off condition.

- V_{DD}/V_{SS} = +15V/−15V with ±35V max applied for a duration of 50ms max (voltage spike,10% duty cycle) to all analog inputs simultaneously.

  Under this condition, V_S and V_D are clamped to ±15.7V max.

- V_{DD}/V_{SS} = +15V/−15V with ±35V max applied continuously to any one analog input ($V_{IN1} - V_{IN16}$).

De-Multiplexer Circuit

Figure 2 shows a typical de-multiplexer circuit. In this application it is used to provide a 16-channel sample-and-hold circuit, allowing 16 separate digitally programmable voltages to be generated from the output of a single DAC.

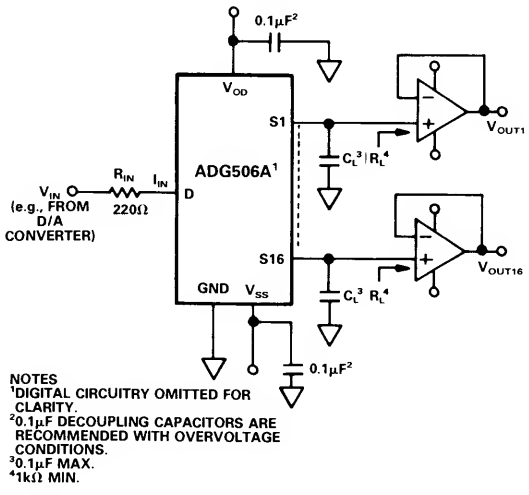

Figure 2. ADG506A De-Multiplexer Circuit

*TransZorb is a trademark of General Semiconductor Industries, Inc.

R_{IN} (220Ω) provides the necessary overvoltage protection.This protection is required if, for example, the supplies to the multiplexer are turned off but the supplies to the DAC are still present (e.g., separate supplies). However, the multiplexer is sufficiently robust when powered-off to allow the stored charge on C1 – C16 (0.1μF max) to discharge through it without causing failure. The protection outlined applies over the −40°C to +85°C temperature range for the following condition:

- V_{DD}/V_{SS} = GND with ±15V max applied continuously to V_{IN}.

  With this condition, V_S and V_D are clamped to ±0.7V max. I_{IN} is limited to 65mA max (14.3V/220Ω). In general, R_{IN} is not required because the output short circuit current of an op amp or a voltage output DAC is limited to less than 65mA.

  Power on/off is also allowed (0.5 second max timing skew) with V_{IN} = ±15V. If the supplies go high impedance or open circuit in the off condition, 15V TransZorbs should be connected from V_{DD} and V_{SS} to GND.

ADVANTAGES OF EXTERNAL PROTECTION

The overvoltage protection outlined above uses external current limiting resistors in series with the S (D) inputs of the multiplexer. These resistors could also be incorporated on-board the die of the multiplexer, but this would lead to power dissipation problems and therefore restrict the overvoltage amplitude allowed. Overvoltage protected multiplexers from some manufacturers use on-chip resistors (with the associated power dissipation problem), but these are employed to protect the S inputs only. This means that in the de-multiplexer application shown in Figure 2, an external resistor (R_{IN}) is still required if the source of V_{IN} can supply greater than 65mA. In this instance, on-chip resistors actually cause problems by increasing the settling time of the sample-and-holds. In conclusion, external versus internal protection is preferable for the two reasons outlined above.

Note: The information furnished in this application note is believed to be accurate and reliable. It is based on experimental results from three fabrication lots. However, no responsibility is assumed by Analog Devices for its use.